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Towards a national indicator for urban green space provision and environmental inequalities in Germany: Method and findings

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Towards a national indicator for urban green space provision and environmental inequalities in Germany: Method and findings[1]

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Abstract

Action 5 of the EU 2020 Biodiversity Strategy explicitly mentions that member states will map and assess the state of ecosystems and their services in their national territory by 2014 with the assistance of the Commission. Access to urban green is a key contributor to social and ecological functions in urban environments. However, in Germany - like in many other European countries - a national indicator measuring the provision of urban green on household and individual level is missing. This study develops a national indicator for urban green space provision and environmental inequalities in Germany on household and individual level. We investigate the provision of urban green by merging geo-coded household data from the German Socio-Economic Panel (GSOEP) and census population data with geo-coded data on land use from the European Urban Atlas (EUA) for German major cities with more than 100.000 inhabitants. Based on open green space standards applied in European urban city planning we define two variables measuring access to green: First, we estimate the distance to urban green measured as the Euclidean distance between the household and the nearest green-

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site in meters. Secondly, we calculate the coverage of urban green space around the households in square meters. Results of the distance analysis based on GSOEP data show a mean and median distance to public green space of 229.1m and 190.5m, respectively. The results further indicate that 93% of the German households have access to green space within a 500m and 74.1% within a 300m buffer around their location. The average green space provision in German major cities adds up to 8.1m^2 per capita (median). Moreover, statistical analysis of the socio-economic background of the households shows differences in urban green provision related to income, education, employment status, migration background and nationality. We also identify differences in green space provision on the city level ranging from 10.6ha (city of Frankfurt/Oder) to 1.2ha (city of Schwerin) green space within 500m around the household. Distances to the nearest urban green also vary between cities ranging from 99m (city of Frankfurt/Oder) to 349m (city of Schwerin). The coverage of green space per capita ranges from 36m^2 (city of Bergisch Gladbach) to 2.5m^2 (city of Schwerin). We also provide a ranking of German major cities based on the green space provision on city level. The analysis further shows an unequal distribution of green within cities. The findings provide helpful information for policy and planning to ensure an adequate green space provision and to eliminate related environmental inequalities in Germany.

Keywords: Urban Green, Indicator, Household and individual level, Geocoded data, Environmental inequities

JEL: Q56, Q58, R14, R20, R52

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1. Introduction

Urban ecosystems and their services play an important role for human well-being. However, as urbanization and densification processes put increasing pressure on open space, concerns over the preservation of urban green have been growing in recent years. In order to halt the loss of biodiversity and to improve the state of Europe's biodiversity and ecosystem services, the European Commission adopted the EU 2020 Biodiversity Strategy on 3 May 2011. Under action 5 "Improve knowledge of ecosystems and their services in the EU" of the strategy, it is explicitly mentioned that member states, with the assistance of the Commission, will map and assess the state of ecosystems and their services in their national territory by 2014 and assess the economic value of such services to promote the integration of these values into accounting and reporting systems at the EU and national level by 2020. Therefore,

activities such as mapping and assessment of ecosystem services represent an essential part of the EU 2020 Biodiversity Strategy. As a consequence, the EU Member States initiated activities to develop indicators assessing the state of ecosystems and their services (European Commission, 2014). The state of the art of defining indicators to implement the "Mapping and Assessment of Ecosystems and their Services (MAES)" process in Germany is reported by Albert et al. (2016).

The provision of a sufficient amount of urban green represents a key aspect for adequate living conditions and a healthy environment in urban areas (Krekel et al., 2016; Nowak and Heisler, 2010; Cornelis and Hermy, 2004; Zupancic et al., 2015). The relevance of urban green for human well-being and sustainable development of urban areas has led to the development of targets and thresholds for urban green provision at European, national and subnational levels. In Europe, the European Environment Agency (EEA) defines the green space provision target that people should have access to green space within 15 min walking distance, which is approximately 900-1.000m (Stanners, David and Philippe Bourdeau, 1995). The Netherlands target a minimum green provision of $60m^2$ per-capita within a $500m$ radius around household (Roo et al., 2011) while in the UK, urban dwellers should have access to $2ha$ of urban green within a $300m$ distance from the place of residence (Handley et al., 2003). The National Strategy on Biological Diversity in Germany (BMU, 2007) sets the target that every household in Germany should have access to urban green within walking distance. Other targets on the municipality level are incorporate, among others, by the City of Berlin and the City of Leipzig, targeting a minimum amount of green space provision of $6m^2$ and of $10m^2$ per-capita, respectively (Kabisch and Haase, 2014). Therefore, targets for urban green provision can significantly differ between municipalities in Germany. However, neither an indicator for urban green provision nor a monitoring system exists at the national level in Germany.

In response to the relevance of urban green for human well-being and the sustainable development of urban areas, a considerable amount of literature investigates the provision of urban green space (see La Rosa, 2014, for an overview). Fuller and Gaston (2009) examine the relationship between urban green space coverage, city area and population size of 386 European cites. Study results demonstrate that per-capita green space provision ranges from low values in the south and east (3 to $4m^2$ per person in Spain and Italy) to increased provision in the north and northwest of Europe ($300m^2$ in Belgium and Finland). Kabisch et al. (2016) show that the share of the population in European cities living within a $500m$ and a $300m$ distance to green and forest areas with a minimum size of $2ha$ ranges from 11% to 98%. For the

city of Berlin, Germany, they found that 30% of the population lives within a $300m$ and 68% within a $500m$ distance. Van Herzele and Wiedemann (2003) developed an integrated indicator to monitor green provision in four Belgian cities by evaluating the accessibility and quality of urban green and show that in Antwerp, Ghent and Aalst no quarter greening (maximum $800m$) is available for about 35% of the population, while in Kortrijk this rises to 95%. Barbosa et al. (2007) analyse access to green space in Sheffield (UK) and found that 64% of the households fail to meet the recommendation of the regulatory agency English Nature (EN), which states that people should live no further than $300m$ from their nearest green space. Moreover, they found that distances of households to green space vary greatly across Sheffield with a mean distance to public green space of $416.8m$. Sotoudehnia and Comber (2011) found that only 15% of the total population in Leicester lives within $300m$ distance ito green space. In the French city of Nantes, which has won the title of European Green Capital in 2013, 100% of the population lives within a $300m$ to green space. The first Environmental Assessment for Europe showed significant differences in green space provision between European cities ranging from Brussels, Copenhagen and Paris where all citizens live within 15 minutes walking distance from public green, and Venice and Kiev where the corresponding figure is 63% and 47% of the population (Stanners, David and Philippe Bourdeau, 1995).

A second strand of literature focuses on environmental justice and inequalities in green space provision by incorporating data on the socioeconomic background of households and individuals (Astell-Burt et al., 2014; Germann-Chiari and Seeland, 2004; Pham et al., 2012; Shanahan et al., 2014, e.g.). Germann-Chiari and Seeland (2004) merge green data with social demographics for particular social groups (youths, elderly people, foreigners, unemployed) for three Swiss major cities (Geneva, Lugano, Zürich) and found mixed results indicating that green space is evenly distributed over the whole city of Lugano but not for a significant negative correlation between green space availability and heterogeneity of social groups in the city of Zurich. Comber et al. (2008) analyse access to green for different ethnic and religious groups in English cities and found Indian, Hindu and Sikh groups to have limited access to greenspace. Pham et al. (2012) investigate environmental inequity in Montreal (Canada) resulting from variations in urban vegetation by using socio-demographic variables obtained from the Canada Census and rescaled to the city block level. The analysis found disparities in the distribution of vegetation in Montreal disfavouring low-income people and, to a lesser extent, visible minorities. Heckert (2013) explores different methods of measuring access to green space in Philadelphia and their implications for assessing equity in green space access based on socioeconomic status.

The analysis shows that Blacks and Hispanics tend to live closer to public greenspace than whites, but live in proximity to smaller overall amounts of greenspace. Barbosa et al. (2007) examine how access to green space in Sheffield (UK) differs across different sectors of society and found access to public green space to vary significantly across different social groups (Twilight Subsistence, Symbols of Success etc.). The greatest access include more deprived groups and elderly people. Kabisch and Haase (2014) investigate distributional inequities between green space and population with respect to demographics and immigrant status in the City of Berlin (Germany) on 60 sub-district areas and identify considerable dissimilarity by immigrant status and age. Moreover, Astell-Burt et al. (2014) analyse green space distribution in Australia's most populous cities (Sydney, Melbourne, Perth, Adelaide) and show that green space availability is substantively lower in statistical areas with a higher percentage of low income residents.

However, most of the available investigations restrict their analysis either to particular cities (Kabisch and Haase, 2014; Heckert, 2013; Heynen, 2003; Pham et al., 2012, e.g.) or - in the case studies analysing green space provision on a national level - they do not control for the socioeconomic background of households and individuals (Stanners, David and Philippe Bourdeau, 1995; Fuller and Gaston, 2009, e.g.). This paper contributes to the existing literature by developing an indicator for urban green provision and environmental inequalities on household and individual level in Germany. To assess urban green space provision on national level we merge geocoded panel data on the socio-economic background of households (e.g. income, age, education, migration background) from the German Socio-Economic Panel (GSOEP) and census population data with geocoded data on urban green in German major cities.

2. Data and methods

The overall purpose of this study is to develop a national indicator for urban green provision in German major cities and to investigate whether access to green space differs with respect to the socio-economic background of German households and individuals. The analysis requires specific geocoded land use data and geocoded household data on the socio-economic background and density of German households and individuals.

2.1. Urban land use data

In order to investigate green space availability we use cross-section data from the European Urban Atlas (EUA) of the European Environment Agency (EEA) recorded in 2006 (European Environment Agency, 2011). The EUA

is a comprehensive and comparative cross-section study, which provides land cover data for European major cities with more than 100,000 inhabitants including data on urban land use for 53 of the 77 major German cities (European Environment Agency, 2011).[2] The EUA provides geocoded information on the geographical locations of urban green, allowing to merge data on green space with geocoded information on the location of German households including their socio-economic background. In our analysis we focus on the two most important urban green categories: "green urban areas" and "forest". According to the EUA, the class "green urban areas" contains public green areas for predominantly recreational use, such as gardens and parks. Not included in the green urban areas are private gardens within housing areas and cemeteries. The "forest" class contains land that has a ground coverage by a tree canopy of more than 30% with tree heights of more than $5m$, including bushes and shrubs at the fringe of the forest. Forests within urban areas and/or subject to human pressure are included in the class urban green areas (see table A.1). Since other green space categories such as private gardens, cemeteries and land mainly used for sports and leisure are often subject to a number of restrictions (entrée fees, opening hours etc.) we decided to leave these categories out.

Table A.1 about here

In comparison to other geocoded land use data potentially available for German major cities, the EUA holds several advantages (Hoymann, 2013). First, the spatial resolution of the EUA in urban areas with more than 100,000 inhabitants is higher than the spatial resolution of other land use data bases such as ATKIS and CORINE land cover. Second, the use of the

[2]We restrict the data to the 54 major German cities with greater or equal to 100,000 inhabitants. The major German cities with more than 100,000 inhabitants include the city of Augsburg, Bergisch Gladbach, Berlin, Bielefeld, Bochum, Bonn, Bottrop, Bremen, Darmstadt, Dortmund, Dresden, Duisburg, Düsseldorf, Erfurt, Erlangen, Essen, Frankfurt am Main, Freiburg im Breisgau, Fürth, Gelsenkirchen, Göttingen, Hagen, Halle an der Saale, Hamburg, Hamm, Hannover, Herne, Karlsruhe, Kiel, Koblenz, Köln, Leipzig, Leverkusen, Magdeburg, Mainz, Moers, Mönchengladbach, Mülheim an der Ruhr, München, Neuss, Nürnberg, Oberhausen, Offenbach, Potsdam, Recklinghausen, Regensburg, Saarbrücken, Stuttgart, Trier, Wiesbaden and Wuppertal. Although the city of Schwerin and Frankfurt/Oder have only 92,000 and 60,000 inhabitants, we include these cities to increase the size of the final sample.

EUA is free of charge and is updated on a regular basis potentially allowing to monitor the development of green space provision over time.[3]

2.2. Household data

The indicator for green space provision in Germany focuses on the following aspects:

- Distance to green space between household and the nearest green site
- Total amount of green space available for each German household neglecting other households in the near vicinity competing for green space
- Urban green space provision per capita accounting for other households in the close vicinity competing for the available green space
- Urban green provision with respect to the socioeconomic background of households and individuals

The analysis of these aspects requires geocoded information on (i) the location of the households and (ii) information on the socio-economic background of households and individuals. The German Census data provide information on the density of German households on city block level allowing to estimate the total amount of green space available for each German household and the green space provision per capita (see section 2.2.1). Due to the strict data protection policy in Germany the Census data provides no information on the socioeconomic background of households and individuals. We therefore apply a second data base - The German Socio-Economic Panel (GSOEP) - to assess the provision of urban green on household level with respect to the socio-economic background of households and individuals (see section 2.2.2).

[3]Most of the major cities in Germany are undergoing a process of expansion by incorporating neighbouring villages and smaller municipalities resulting in an ongoing extension of the administrative boundaries of the municipalities. As a result the administrative boundaries of many German major cities lie outside the actual urban land use areas characterized by high population density and a high share of sealed surface for settlement and industrial land. For example, around 75% of the municipality of Freiburg lies outside areas defined as urban land use (urban fabric, industrial and private units etc.) with densely populated areas. Since the overall purpose of this analysis is to develop an indicator for urban green space provision we restrict our analysis to urban areas and land mainly used for settlement, industrial purposes and mixed zones.

2.2.1. German Census data

The German Census data (GCD) provides information on the number of residents in Germany based on a $100 \times 100m$ grid[4] (inhabitants per hectare as a result of the National Census on May 9, 2011) (Statistische Ämter des Bundes und der Länder, Results of the Census 2011). The population data comprise around 20 million georeferenced addresses of the municipal registers (Kleber et al., 2009) providing detailed information on the population density in German municipalities and is updated on a regular basis (every ten years). The Census allows for spatial analysis based on each grid cell and therefore offers the possibility to calculate the green space provision for the population within a particular grid cell. For the calculation itself, the centroids of each grid cell are merged with data on urban green from the EUA. The results of the computationally intensive calculations are the distance to the nearest green space and the coverage with urban green in a predefined $500m$ buffer around the centroid of the grid cell. Data for grid cells with less than two residents are excluded from the data set and grid cells with two residents are treated as if having three, yielding a minimum population of three residents for all inhabited grid cell. The bias resulting from this falsification should be rather small regarding the overall sample size. Grid cells with five or less than five inhabitants, for example, account for only 0.2% of the whole sample of more than 18 million residents. Due to the strict data protection policy in Germany, the Census data provides no information on the socio-economic background of the households.

2.2.2. German Socio-Economic Panel

In addition to the German Census, we use panel data from the German Socio-Economic Panel (GSOEP) for the year 2006 to assess the provision of urban green on household (and individual) level with respect to the socioeconomic background of the households and the individuals, respectively. The GSOEP is a comprehensive and representative panel study of private households in Germany, including almost 11,000 households and 22,000 individuals every year. It provides information on all household members, covering Germans living in the old and new federal states, foreigners, and recent immigrants (Wagner et al., 2007, 2008). Moreover, the GSOEP provides information on the geographical locations of the places of residence of individuals, allowing to merge data on the socioeconomic background of the households with data on urban green through geographical coordinates. As such, the GSOEP is not only representative of individuals living in Germany

[4]INSPIRE compliant.

today, but also provides the necessary geographical reference points for our analysis.[5] The GSOEP provides comprehensive information on all relevant household characteristics (e.g. income, education, migration, employment). In contrast to the Census data on the distribution and density of households in a one hectare grid level, the GSOEP data allow for incorporating data on the socioeconomic background of the residents and exactly merging data on the location of the respective households with data from the EUA. Throughout our analysis, the following variables (on individual and household level respectively) from the GSOEP survey are used: migration, income, education, age, employment status, sex, nationality, household size.

2.3. Method/Approach

In order to investigate green space availability in German major cities, we merge the geocoded land use data of the EUA with the household data drawn from the German Census and the GSOEP. Moreover, we define a set of variables measuring provision of urban green space on household level. First, we compute the distance to the nearest urban green space measured as the Euclidean distance between the household and the border of the urban green site. The distance variable therefore serves as a proxy how long it takes to reach the nearest urban green space site. Second, we define coverage of urban green space measured as the square meters covered by urban green space in a predefined buffer area of $500m$ around households and grid centroids respectively.[6] The coverage variable works therefore as a proxy for the quality of urban green space in the close proximity to the household. The coverage variable also allows for estimating the per capita green provision – a figure that is especially important in the context of urban planning.

Even though the two green variables (distance and coverage) are to a large extent negatively correlated, they vary under certain circumstances, e.g. when the Euclidean distance to the nearest patch of green space is

[5]The GSOEP is subject to rigorous data protection regulation. It is never possible to derive the household data from the coordinates since they are never visible to the researcher at the same time. For more information on the data protection regulation see Göbel and Pauer (2014).

[6]Thresholds from planning often define a sufficient access to green space as a particular amount of green within walking distance to the household. There is no clear definition of "walking distance" in the literature (Kienast et al., 2012; Barbosa et al., 2007; Panduro and Veie, 2013). We define "walking distance" in our analysis as a maximum distance of $500m$ from the household and measure green space provision as the coverage of urban green in a buffer of $500m$ around the household. However, we also provide information on the percentage of households having access to green space within a $300m$ buffer around the household.

rather short but the spatial coverage of urban green space within the area of interest is comparatively low. Therefore, both variables do not necessarily represent substitutes. From an economic point of view, distance expresses the price of the commodity ("How long it takes to get there") while spatial coverage often indicates the quality of green space (e.g. size of the park).

Figure A.3 about here

In order to analyse the provision of urban green space in relation to the socioeconomic background of the households, we control for household characteristics such as age, income and employment. Table A.2 illustrates all variables used in our analysis. Some of the variables can be drawn from both data base (e.g. total coverage of green, Distance to green). For others, it is only possible to draw them from one of the data bases (e.g. coverage per capita, distance-background, total coverage-background). Therefore, our approach does not only allow for calculating green space provision in Germany on a household and individual level but also for comparing the findings of the different data bases as a robustness check (see figure A.3). In addition, it enables us to differentiate between German major cities regarding green space provision (see chapter 2.3).

Table A.2 about here

3. Results

Table A.5 (Appendix) provides a descriptive statistics of the GSOEP study sample used in this analysis. Overall, 4,588 households of the GSOEP sample are located in the 53 German major cities. Since population statistics in Germany are collected with respect to the administrative boundaries of the municipalities, it is not possible to compare our study sample with the entire urban population in Germany.

3.1. General green space provision in Germany

The analysis of the general green space provision in Germany based on the German Census shows an average distance between the households and

the nearest green space site of $221m$ (see table A.3) meaning that 92.8% of the German urban population lives within a maximum distance of $500m$ (74.1% within a maximum distance of $300m$) between place of residence and the nearest green. The analysis with the GSOEP household data shows that a German household lives – on average – within a distance of $229m$ to the nearest green space site.

Table A.3 about here

The average green space coverage in a $500m$ buffer around a German household amounts to $6.6ha$ ($8.11m^2$/capita) (GCD data) and $6.8ha$ (GSOEP data). Therefore, the Census data results confirm the findings from the GSOEP data and vice versa (see table A.3).

Figure A.1 about here

3.2. Green space provision in Germany with respect to the socio-economic background of households

Table A.6 and Table A.7 (Appendix) show green space provision (distance, coverage) based on the household data drawn from the GSOEP with respect to the socioeconomic background of the households and individuals. Table A.4 presents test statistics for the urban green variables (distance and coverage) applying Welch's t-test. The results of the test statistics for distance to green space show significant differences in green space provision for income. The mean distance to green of the income class "<1,300 Euro" ($239.98m$) is significantly higher than the mean distance to green of the income class "5,000 Euro and more" ($214.37m$). The tests for the coverage variable show also significant differences in green space provision with respect to the socio-economic background of the households. The mean coverage of green for the income class "<1,300 Euro" ($58,069.68m^2$) is significantly lower than the mean coverage of green for the income class "5,000 Euro and more" ($81,709.08m^2$). The mean coverage of green for the education class "lower than secondary degree" adds up to $61,923.33m^2$ and is therefore significantly lower than the mean coverage of green for the education class "With tertiary degree" ($73,593.34m^2$). Employed residents have access to

$62,226.87m^2$ urban green within a $500m$ around location of their residence. This is significantly more than unemployed residents have $(60,552.04m^2)$. The mean coverage for residents having a German nationality amounts to $69,135.36m^2$ while foreign residents have access to $61,289.36m^2$. Moreover, single households find with $62,742.98m^2$ significantly less green space in close vicinity than four and more person households $(78,080.34m^2)$.

Table A.4 about here

3.3. Green space provision in Germany on city level

The results from the analysis of the general green space provision in Germany show a mean distance to the nearest green site of $221m$ and a mean coverage in a $500m$ buffer of $6.6ha$ $(8.11m^2/\text{capita})$. Based on the German Census data we also analysed whether green space provision differs between German major cities and how the green is distributed throughout the cities. Table A.8 and A.9 (Appendix) illustrate green space provision (distance and coverage) for the 53 major cities in our sample. The results indicate differences in green space provision on the city level ranging from Frankfurt/Oder with the highest green space provision per capita of $105,943m^2$ and Schwerin with the lowest green space provision of $12,210m^2$ (median). The coverage of green space per capita ranges from $36m^2$ in the city of Bergisch Gladbach to $2.5m^2$ in the city of Schwerin (median). Distances to the nearest green space can also highly vary between cities ranging from $99m$ in Frankfurt/Oder to $349m$ in Schwerin (median). For a ranking of German major cities based on the green space provision on city level see table A.10 (Appendix).

Figure A.2 about here

The analysis of the distribution of green space coverage per household within cities shows an unequal green space distribution for the city of Hamburg (see figure A.2), Cologne (see figure A.4) and Munich (see figure A.5). Regarding the relatively small number of GSOEP participants per city, a comparison between cities would be very prone to error on bias originating from the rather small sample sizes.

4. Discussion and conclusions

Our analysis shows a mean and median distance to public green space of $276.9m$ and $215.9m$, respectively. Therefore 93% of the German households live in close vicinity ($< 500m$) to urban green (74.1% of the households have access to green space in a $300m$ buffer). The average urban green provision amounts to $8.1m^2$ per capita in German major cities. Moreover, the statistical analysis of the socio-economic background of the households and individuals shows differences in urban green provision related to income, education, employment status, migration background and nationality. The analysis further shows differences in green space provision on municipality level between German major cities ranging from Frankfurt/Oder with the highest green space provision per capita of $105,943m^2$ and the city of Schwerin with the lowest green space provision of $12,210m^2$ per capita. Compared with the recommendations of the UK (Handley et al., 2003), the majority of German cities fulfil the per-capita threshold of $2ha$ within a $300m$ distance. Fuller and Gaston (2009) investigate green space coverage in European cities by simply dividing the amount of green space per city through the inhabitants and identify ranges of green space per capita from 3 to $4m^2$ per capita (e.g. Cádiz-Spain) and more than $300m^2$ (e.g. Liège-Belgium). In the Netherlands a green space provision of $60m^2$ per capita is recommended (Roo et al., 2011). Compared with these figures our mean value of $8.1m^2$ per-capita green space provision in German major cities is low. Other studies investigating green space provision on municipality level find a mean distance to the next green of $416.8m$ (Barbosa et al. (2007) which is significantly higher than our findings ($229m$). Barbosa et al. (2007) also found that 64% of households in Sheffield do not live within a distance of $300m$ to the next urban green. Therefore, green space provision in Sheffield differs strongly from our findings (74,1% of households live within a $300m$ distance from green). Sotoudehnia and Comber (2011) investigate green space supply in Leicester. Their findings show a considerably lower green space provison with only 15% of the population living in a $300m$ distance to the next urban green space. Moreover, Kabisch et al. (2016) show that 68% of the German population lives in a $500m$ radius to green space (minimum size $2ha$), which is considerably lower than our findings of 98%. One explanation for this inconsistency between the findings might be the relatively small minimum size of green space of $0.25ha$ in our analysis compared to the $2ha$ minimum size of green space used in the study by Kabisch et al. (2016).

Other than analysing the overall provision of green spaces in the urban setting, the investigation on environmental inequities provides helpful information for policy and planning regarding the elimination of inequalities in

green space access. Findings from Hedonic pricing studies investigating the impact of green space on house prices prove a capitalization of urban green in real estate prices (Kong et al., 2007; Morancho, 2003). Due to the continuously increase in real estate prices in many German municipalities it is likely that inequalities in green space will further increase in the future.

One crucial aspect for the implementation of an indicator measuring green space provision over time relates to future data availability. Since the presence of urban green space is rather persistent of time in Germany (Krekel et al., 2016) most of the changes in green space provision per capita and related environmental inequalities will result from changes in population density and social segregation. Therefore the availability of geocoded statistical data on population density and social background of households and individuals is of major importance. The EUA land cover data are subject to interval data recording and available for the year 2006. The second wave of the EUA is now available allowing to compare the findings of the 2006 data with the 2012 data. According to EU legislation (Regulation EC No 763/2008), the German Census is updated on a regular basis but only once every 10 years (the next Census will be conducted in 2021). The GSOEP on the socioeconomic background of private households and individuals in Germany is collected on a regular basis every year. Taking into account the data availability in Germany, it is principally possible to report the development of green space provision per capita and the mean distance to green for all German households every ten years. Changes in urban green provision with respect to the socioeconomic background of households and individuals would be principally possible on a yearly basis.

The more comprehensive data sources allow for constructing a bottom up indicator for green space provision. Nevertheless, the distribution of such an aggregated indicator has some very specific peculiarities regarding its tails. On the lower tail the distribution is truncated at zero, and on the upper tail, we observe some very large outliers. This results in a typical situation, where the mean tends to be larger than the median of the distribution. We, therefore, recommend reporting the median of the distribution of the indicator instead of the mean, as the median is not affected by outliers in either direction.

AppendixA. Tables and Figures

Table A.1: Land Use Categories incorporated in the analysis for UGS provision. (Soure: European Envoronmental Agency)

Land Use Category		**Relevant sites**	**EUA category**
Green Urban Areas	Inculdes all land for predominantly recreational use; not included are private gardens within housing areas, cemetries, agricultural areas, sports and leisure facilities	parks, gardens, zoos, castle parks	1.4.1
Forests	Includes all forest sites with ground coverage of tree canopy $> 30\%$ and tree height $> 5m$		3

Table A.2: Data base and derived variables measuring green space provision

Data base	**Variables**	**Explanation**
German Census Data (GCD)	Distance	Euclidian Distance to the nearest green site
	Total coverage	Total coverage of green space in a $500m$ buffer around the grid cell centroid
	Coverage per capita	Coverage of green space in a $500m$ buffer around the grid cell centroid per capita
German Socio-Economic Panel (GSOEP)	Distance	Euclidian Distance to the nearest green site
	Distance-`background`	Euclidian Distance to the nearest green site with respect to the socioeconomic background of the household
	Total coverage	Total coverage of green space in a $500m$ buffer around the household
	Total coverage-`background`	Total coverage of green space in a $500m$ buffer around the household with respect to the socioeconomic background of the household

Table A.3: General Green space provision in Germany. (Source: German Census 2011; GSOEP 2006; European Urban Atlas; own calculations)

	Mean	**Median**	**Std.Dev.**	**Min**	**Max.**	**N**
Distance to green (m)						
German Census 2011	221.30	182.98	173.95	0	794.74	18206466
GSOEP 2006	229.13	190.46	176.92	0	1258.86	4588
Coverage of green in $500m$ **buffer** (m^2)						
German Census 2011	66315.4	44467.7	70012.99	0	322609.5	18206466
GSOEP 2006	68483.8	46172.01	72835.26	0	512509.8	4588
Coverage of green in $500m$ **buffer per capita** (m^2)						
German Census 2011	22.34	8.11	168.83	0	210.66	18206466

Table A.4: Test statistics for urban green variables (Source: GSOEP; own calculations

Variable	**Value**		
	Distance to green		**t-statistics**
Migration	Yes	No	0.024
Income	below 1300 Euro	above 5000 Euro	**2.074**
Education	Lower than second degree	With tertiary degree	0.684
Age	$\leq$ 24 Jahre	50 - 64	-0.969
Employment	employed	unemployed	-1.957
Gender	female	male	0.976
German nationality	Yes	No	1.068
Household size	single	4 or more person	1.780
	Coverage of green in $500m$ **buffer**		
Migration	Yes	No	-1.810
Income	below 1300 Euro	above 5000 Euro	**-4.361**
Education	Lower than second degree	With tertiary degree	**-3.396**
Age	$\leq$ 24	50 - 64	-0.401
Employment	employed	unemployed	**2.595**
Gender	female	male	-0.217
German nationality	Yes	No	**2.114**
Household size	single	4 or more person	**-3.446**

Table A.5: Descriptive Statistics GSOEP Sample (Source: German Socio-Economic Panel; own calculations)

Variable	**Mean/Share**	**N**
Age	48.8	4588
18-24	0.09	447
25-49	0.43	1960
50-64	0.25	1146
65 and more	0.23	1035
Gender		
female	0.53	2424
male	0.47	2164
Household Size		
single	0.29	1332
two person	0.53	2450
three person	0.12	546
four and more	0.06	260
German Nationality		
yes	0.92	4207
no	0.08	381
Migration Background		
yes	0.18	799
no	0.82	3774
Education		
lower than *secondary* degree	0.15	650
with *secondary* degree	0.50	2189
with *tertiary* degree	0.35	1527
Employment Status		
employed	0.91	4195
unemployed	0.09	393
Monthly Household Income	3033.93	4561
below 1300	0.22	615
1300-2600	0.38	1072
2600-3600	0.17	470
3600-5000	0.12	332
5000 and more	0.11	300

Table A.6: Distance to green and socioeconomic background (Source: GSOEP; own calculations

Variable	Mean	Median	Std.Dev.	Min.	Max.	N
Migration						
Yes	229.46	194.46	176	0	1258.86	4588
No	229.30	189.06	179.94	0	1258.86	3774
Income in Euro						
below 1300	239.98	208.79	175.79	0	941.93	615
1300-2600	229.43	189.95	176.61	0	1221.7	1072
2600-3600	246.92	198	193.13	0	1205.8	470
3600-5000	212.01	175.75	158.03	0	803.04	332
5000 and more	214.37	163.44	175.07	0	1258.86	300
Education						
Lower than second degree	229.65	199.49	164.43	0	908.09	650
With second degree	233.02	192.22	181.51	0	1258.86	2189
With tertiary degree	224.26	181.83	176.43	0	1258.86	1527
Age classes						
under 24	227.64	188.17	176.46	4.3	1197.06	447
25-49	228.07	190.98	170.03	0	1258.86	1960
50-64	237.37	197.68	188.76	0	1205.8	1146
65 and older	222.66	181.3	176.27	0	1144.49	1035
Employment						
employed	227.67	187.04	178.05	0	1258.86	4195
unemployed	244.71	208.7	163.71	0	1197.06	393
Gender						
female	231.54	192.37	177.54	0	1286.86	2424
male	226.43	187.03	176.33	0	1286.86	2164
German nationality						
Yes	229.87	190.89	178.85	0	1258.86	4207
No	220.94	187.05	153.94	0	794.82	381
Household size						
single	233.68	193.1	184.32	0	1221.7	971
2 person	229.69	191.35	173.99	0	1205.8	1063
3 person	244.42	216.55	171.42	4.3	1197.06	372
4 and more	215.001	166.2	172.61	0	1258.86	397

Table A.7: Coverage with green in 500m buffer and socioeconomic background (Source: GSOEP; own calculations

Variable	Mean	Median	Std.Dev.	Min.	Max.	N
Migration						
Yes	64291.57	42052.73	67308.98		505330.4	799
No	69115.11	46406.08	73490.89	0	512509.8	3774
Income in Euro						
below 1300	58069.68	38935.96	62643.62	0	492835.3	615
1300-2600	65443.07	42645.16	70635.82	0	505330.4	1072
2600-3600	64279.03	41249.3	71300.55	0	468762.4	470
3600-5000	78108.12	50946.1	81403.52	0	405114.4	332
5000 and more	81709.08	57933.12	83046.65	0	512509.8	300
Education						
Lower than second degree	61923.33	39559.77	70939.73	0	505330.4	650
With second degree	66254.93	45608.13	68458.67	0	410790.5	2189
With tertiary degree	73593.34	48349.53	78740.61	0	512509.8	1527
Age classes						
under 24	66792.65	47894.18	70206.58	0	512509.8	447
25-49	67195.77	44948.4	71003.4	0	505330.4	1960
50-64	68403.14	40626.38	76314.84		512509.8	1146
65 and more	71742.67	51427.03	73430.59	0	492835.3	1035
Employment						
employed	69226.87	46944.67	73707	0	512509.8	4195
unemployed	60552.04	39822.61	62311.92	0	363190.8	393
Gender						
female	68262.8	46102.44	72865.29	0	512509.8	2424
male	68731.36	46375.23	72817.65	0	512509.8	2164
German nationality						
Yes	69135.36	47105.25	73144.85	0	512509.8	4207
No	61289.36	36314.27	69008.04	0	505330.4	381
Household size						
single	62742.98	38067.2	70451.95	0	492835.3	971
2 person	67166.09	46266.23	71989.99	0	505330.4	1063
3 person	65198.4	41028.16	72008.16	0	512509.8	372
4 and more	78080.34	56917.81	76361.33	0	405114.4	397

Table A.8: Cities and distances to urban green space in meter (Source: German Census; Urban Atlas; own calculations)

City	Mean	Median	Std.Dev.	Min.	Max.
Frankfurt (Oder)	120.45	99.27	103.52	0	903.47
Saarbrücken	123.82	103.65	96.59	0	614.33
Erfurt	167.66	124.99	182.53	0	1297.17
Bielefeld	157.09	131.92	120	0	836.88
Bergisch Gladbach	155.9	132.1	113.87	0	540.67
Halle (Saale)	195.26	139.13	202.65	0	1586.96
Bottrop	162.38	143.92	117.1	0	603.43
Freiburg im Breisgau	168.12	148.11	120.18	0	712.15
Moers	171.19	148.46	118.45	0	622.99
Hamburg	181.74	148.78	146.7	0	1239.75
Essen	175.76	149.9	130.72	0	781.15
Stuttgart	177.59	150.24	132.85	0	1039.47
Karlsruhe	178.09	150.41	138.54	0	838.58
Offenbach am Main	175.36	152	131.16	0	620.75
Darmstadt	168.21	152.22	113.92	0	799.56
Magdeburg	203.82	154.59	181.29	0	1401.72
Regensburg	182.73	155.05	163.33	0	1274.62
Duisburg	181.55	156.56	138.13	0	936.99
Nürnberg	204.34	160.85	187.79	0	1604.11
Kiel	185.81	161.62	132.17	0	758.26
Leipzig	194.81	165.26	145.11	0	1245.78
Göttingen	196.2	165.84	156.58	0	992.42
Trier	190.97	166.01	127.9	0	865.62
Potsdam	191.74	167.5	124.55	0	633.4
Bochum	199.77	172.07	143.11	0	893.91
Herne	202.94	174.97	142.33	0	820.23
Mühlheim an der Ruhr	215.02	178.23	152.33	0	896.87
Mainz	215.43	178.56	163.34	0	1125.65
Frankfurt am Main	202.43	178.92	140.91	0	1008.56
Deutschland	221.29	182.98	173.95	0	1804.5
Hagen	201.47	188.33	121.36	0	615.48
Koblenz	216.67	188.33	156.13	0	978.21
Oberhausen	229.24	189.82	171.86	0	868.19
Recklinghausen	207.24	190.49	131.21	0	729.9
Düsseldorf	217.87	190.64	155.53	0	1212.09

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City	Mean	Median	Std.Dev.	Min.	Max.
Augsburg	228.88	190.99	182.43	0	1804.5
Gelsenkirchen	213.24	191.21	143.25	0	802.3
Bremen	232.72	192.57	174.9	0	1110.91
München	225.27	195.24	159.47	0	1161.99
Neuss	276.19	195.86	274.12	0	1428.77
Erlangen	233.26	201.8	165.92	0	922.21
Hannover	234.6	202.02	167.96	0	1045.01
Köln	233.99	204.78	164.69	0	1006.5
Berlin	250.97	208.34	196.97	0	1617.2
Leverkusen	248.79	221.85	175.06	0	1042.06
Dortmund	258.19	227.03	176.88	0	1064.06
Wuppertal	265.11	236.18	179.32	0	844.58
Bonn	284.92	236.69	215.89	0	1489.96
Dresden	299.22	247.08	233.26	0	1278.24
Wiesbaden	300.55	247.75	228.04	0	1433.17
Fürth	290.71	266.79	196.04	0	1180.99
Hamm	308.42	278.73	191.39	0	930.53
Mönchengladbach	323.21	292.57	209.82	0	1098.08
Schwerin	412.79	348.82	282.47	0	1118.34

Table A.9: Cities and coverage of urban green space within $500m$ buffer around the household in m^2 (Source: German Census; Urban Atlas; own calculations)

City	Mean	Median	Std.Dev.	Min.	Max.
Frankfurt (Oder)	115488	105943.3	62829.2	0	297365.5
Bergisch Gladbach	140476.3	104680.6	108571.6	0	550129.1
Saarbrücken	123770.6	93882.88	98988.22	0	592161.7
Bottrop	99306.59	81831.65	75339.13	0	528471.1
Bielefeld	97186.66	79116.08	78211.86	0	582606.5
Duisburg	84058.08	71451.59	67298.86	0	518739.9
Halle (Saale)	87643.61	68732	77250.05	0	594639.5
Essen	85177.79	67517.27	71211.98	0	548744.8
Kiel	79912.68	65386.48	66948.61	0	514109.4
Potsdam	82989.19	64560.96	70290.11	0	435438.7
Neuss	69047.5	64305.86	59183.77	0	327015.6
Darmstadt	90895.09	62221.93	83406.96	0	565616.1
Moers	72580.03	60947.98	55137.33	0	376919.4
Bochum	77015.79	60944.43	67725.33	0	495536
Leverkusen	84593.37	60362.3	81167.58	0	495438.9
Erfurt	71927.71	59577.07	58352.23	0	485899.6
Hagen	80752.74	59363.6	71742.06	0	621680.9
Trier	82206.05	56629.84	77780.22	0	399599.5
Herne	72198.56	53966.06	63563.25	0	477381.9
Hamburg	66312.84	53787	55453.52	0	527283.5
Freiburg im Breisgau	82483.69	52403.95	83674.29	0	556887.1
Gelsenkirchen	76957.75	51972.39	80540.43	0	609429.9
Leipzig	72123.97	51626.75	65410.6	0	535516.1
Stuttgart	82979.96	51025.51	85078.76	0	615900.3
Mühlheim an der Ruhr	62817.71	48509.42	60905.88	0	512454.5
Recklinghausen	63708.53	47046.17	57402.15	0	424896
Köln	71165.22	45782.69	75499.05	0	553654.6
Offenbach am Main	75052.84	45248.03	85621.62	0	635756.3
Karlsruhe	75116.61	44760.8	83219.8	0	553920
Deutschland	66315.43	44467.66	70012.99	0	744349.9
Göttingen	72777.49	44102.5	82011.95	0	528659.3
Oberhausen	71316	43391.59	75106.05	0	605848.6
Hannover	67002.88	43324.57	72530.46	0	632214.2
Regensburg	53578.31	42121.16	41626.77	0	227055.4
Frankfurt am Main	60161.06	41662.73	62545.88	0	478293.7

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City	Mean	Median	Std.Dev.	Min.	Max.
Magdeburg	53574.49	41442.52	50856.94	0	452961.9
Düsseldorf	66903.02	41216.31	73168.06	0	511934.8
Nürnberg	62907.75	40449.45	66023.36	0	557063.9
Dortmund	54542.09	38925.82	61364	0	540831.6
Augsburg	50416.67	38547.06	50281.37	0	590766.7
Mainz	45254.18	37955.59	41835.56	0	404749.7
Wuppertal	73258.8	37377.05	85020.09	0	660176.6
Berlin	57750.99	35694.51	66454.11	0	699143.5
Koblenz	60591.82	35255.49	63893.27	0	510963.1
Bremen	47583.26	34702.47	50436.58	0	411109.3
München	57987.49	33484.16	67237.88	0	526165.4
Bonn	60483.81	30992.07	76615.85	0	515760.4
Erlangen	63301.51	28654.52	84482.33	0	449360.3
Fürth	51932.98	24304.78	70751.7	0	457270.7
Dresden	51034.64	21845.3	72439.42	0	744349.9
Hamm	35946.05	21148.67	43297.58	0	374497.6
Mönchengladbach	42018.74	18669.07	56949.68	0	444309.8
Wiesbaden	47344.16	16141.06	71389.45	0	586416.3
Schwerin	25946.5	12210.39	38718.68	0	286450.5

Table A.10: Cities and rank according to green space provision (Source: German Census 2011; own calculations

	Coverages		Distances		Per Capita	
City	**Mean**	**Median**	**Mean**	**Median**	**Mean**	**Median**
Bergisch Gladbach	1	2	3	5	1	1
Frankfurt (Oder)	3	1	1	1	4	2
Saarbrücken	2	3	2	2	2	3
Bielefeld	5	5	4	4	3	4
Bottrop	4	4	5	7	5	5
Leverkusen	9	15	43	45	10	6
Neuss	29	11	47	40	36	7
Bochum	17	14	23	25	15	8
Duisburg	10	6	14	18	22	9
Trier	14	18	18	23	6	10
Moers	23	13	9	9	25	11
Essen	8	8	11	11	20	12
Recklinghausen	34	26	29	34	16	13
Hagen	15	17	24	31	8	14
Halle (Saale)	7	7	21	6	12	15
Kiel	16	9	17	20	7	16
Potsdam	11	10	19	24	13	17
Herne	24	19	26	26	28	18
Gelsenkirchen	18	22	30	37	9	19
Göttingen	22	31	22	22	18	20
Mülheim an der Ruhr	37	25	31	27	33	21
Darmstadt	6	12	8	15	11	22
Erfurt	26	16	6	3	37	23
Leipzig	25	23	20	21	32	24
Oberhausen	27	32	38	33	17	25
Koblenz	38	44	33	32	26	26
Regensburg	44	34	16	17	47	27
Magdeburg	45	36	27	16	43	28
Hamburg	33	20	15	10	40	29
Freiburg im Breisgau	13	21	7	8	29	30
Dortmund	43	39	45	46	30	31
Stuttgart	12	24	12	12	27	32
Wuppertal	21	42	46	47	14	33
Erlangen	35	48	40	41	31	34

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City	Coverages		Distances		Per Capita	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**
Hannover	30	33	42	42	34	35
Deutschland	32	30	35	30	36	37
Bonn	39	47	48	48	24	37
Karlsruhe	19	29	13	13	19	38
Bremen	49	45	39	38	45	39
Köln	28	27	41	43	39	40
Augsburg	48	40	37	36	52	41
Hamm	53	51	52	52	46	42
Düsseldorf	31	37	34	35	42	43
Offenbach am Main	20	28	10	14	21	44
Mainz	51	41	32	28	54	45
Frankfurt am Main	40	35	25	29	50	46
Nürnberg	36	38	28	19	44	47
Mönchengladbach	52	52	53	53	38	48
München	41	46	36	39	51	49
Dresden	47	50	50	49	23	50
Berlin	42	43	44	44	48	51
Fürth	46	49	49	51	49	52
Wiesbaden	50	53	51	50	41	53
Schwerin	54	54	54	54	53	54

Figure A.1: Maximum distance (m) of population (%) to the nearest green site in Germany. (Source: German Census 2011 and European Urban Atlas; own calculations)

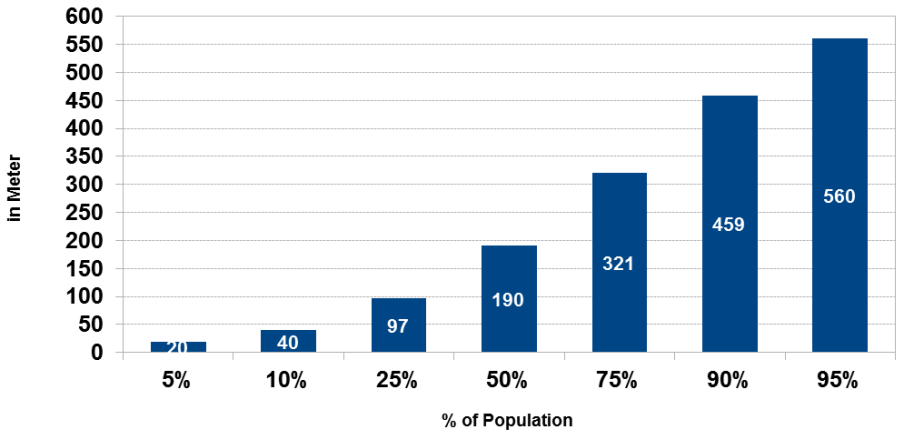


Figure A.2: Heat map for green space distribution (coverage per household) in the city of Hamburg (Source: German Census 2011 and European Urban Atlas; own calculations)

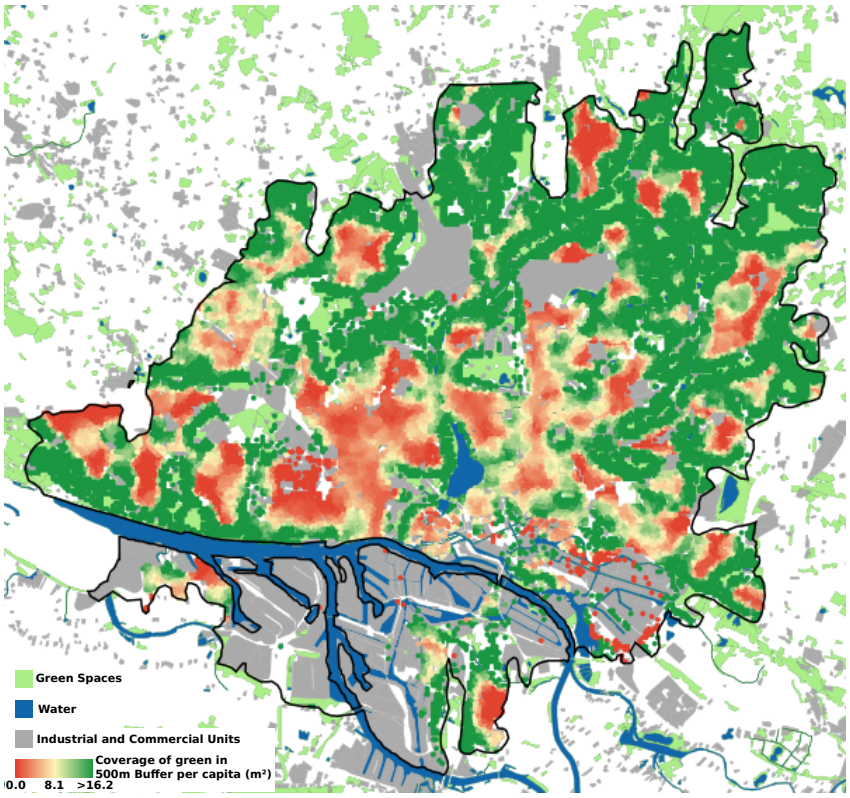


Figure A.3: Data and approach

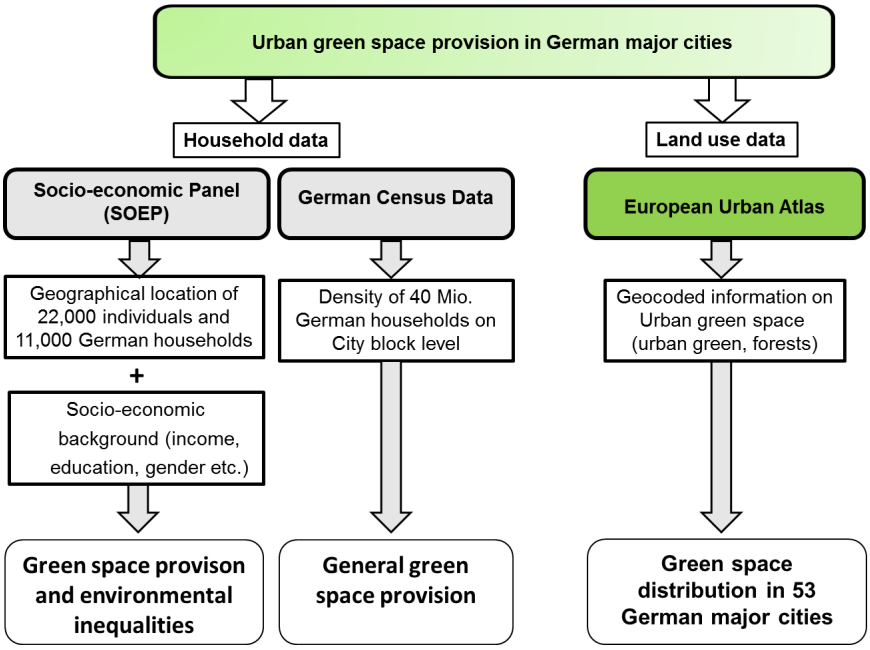


Figure A.4: Heat map for urban green space distribution (coverage per household) in the city of Cologne. (Source: German Census 2011 and European Urban Atlas; own calculations)

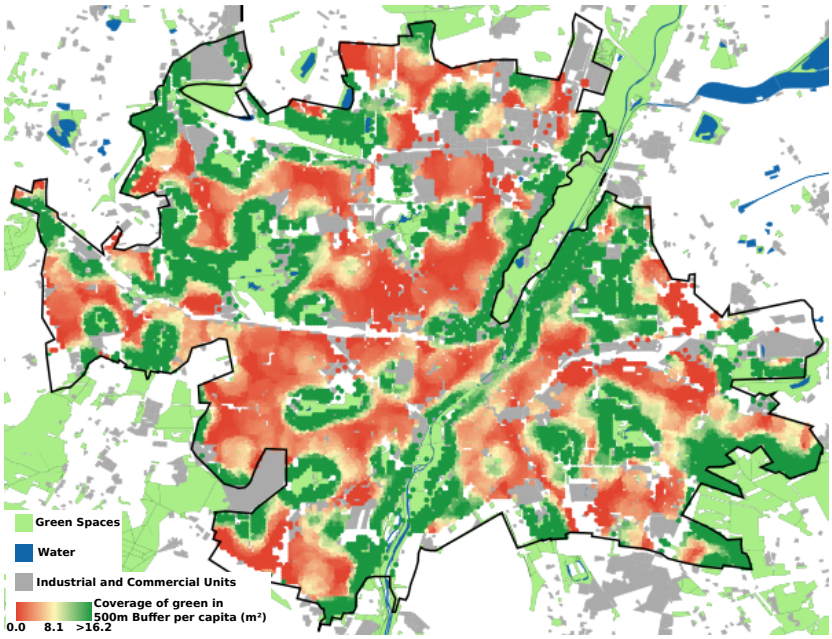
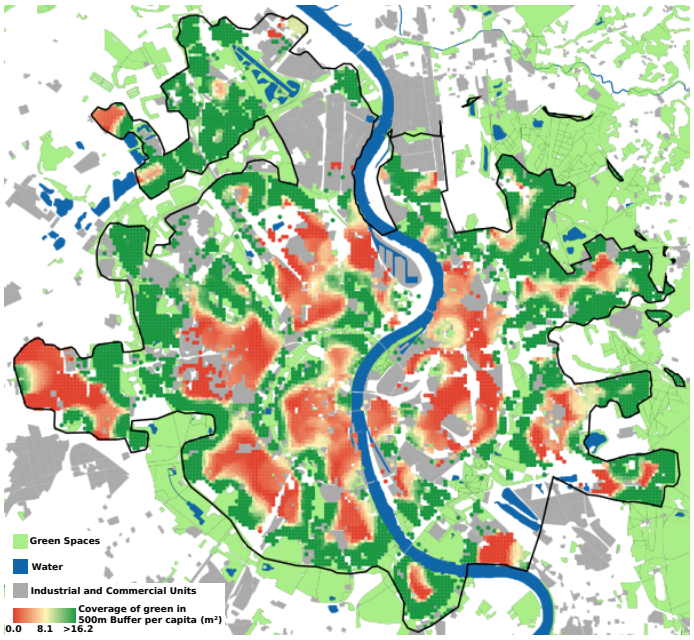


Figure A.5: Heat map for urban green space distribution (coverage per household) in the city of Munich. (Source: German Census 2011 and European Urban Atlas; own calculations)



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